


## ORIGINAL RESEARCH ARTICLE

# Weight loss with bariatric surgery or behaviour modification and the impact on female obesity-related urine incontinence: A comprehensive systematic review and meta-analysis

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## Summary

Women with obesity are at risk of pelvic floor dysfunction with a 3-fold increased incidence of urge urinary incontinence (UUI) and double the risk of stress urinary incontinence (SUI). The National Institute for Health and Care Excellence (NICE) and European Association of Urology (EAU) recommend that women with a body mass index  $\geq 30$  kg/m<sup>2</sup> should consider weight loss prior to consideration for incontinence surgery. This systematic review and meta-analysis will assess this recommendation to aid in the counselling of women with obesity-related urinary incontinence (UI). Medical Literature Analysis and Retrieval System online (MEDLINE), EMBASE, Cochrane, ClinicalTrials.gov, and SCOPUS were systematically and critically appraised for all peer reviewed manuscripts that suitably fulfilled the inclusion criteria established a priori and presented original, empirical data relevant to weight loss intervention in the management of urinary incontinence. Thirty-three studies and their outcomes were meta-analysed. Weight loss interventions were associated in a decreased prevalence in UI (OR 0.222, 95% CI [0.147, 0.336]), SUI (OR 0.354, 95% CI [0.256, 0.489]), UUI (OR 0.437, 95% CI [0.295, 0.649]) and improved quality of life (PFDI-20, SMD -0.774 (95% CI [-1.236, -0.312])). This systematic review and meta-analysis provide evidence that weight loss interventions are effective in reducing the prevalence of obesity-related UI symptoms in women. Bariatric surgery in particular shows greater sustained weight loss and improvements in UI prevalence. Further large scale,

**Abbreviations:** BMI, body mass index; CENTRAL, Cochrane Central Register of Controlled Trials; EAU, European Association of Urology; EMBASE, Excerpta Medica; ICIQ-SF, International Consultation on Incontinence Questionnaire Short Form; IU, Urinary incontinence; KHQ, Kings Health Questionnaire; LAGB, Laparoscopic Adjustable Gastric Band; LVSG, Laparoscopic Vertical Sleeve Gastrectomy; MEDLINE, Medical Literature Analysis and Retrieval System online; MeSH, Medical Subject Heading; National Institute for PFDI-20, Pelvic Floor Distress Inventory; NICE, National Institute for Health and Care Excellence; PRIDE, Program to Reduce Incontinence by Diet and Exercise; PRISMA-P, Preferred Reporting Items for Systematic review and Meta-Analysis Protocols; PROSPERO, International Prospective Register of Systematic Reviews; QoL, Quality of Life; RYBG, roux-en-Y Gastric Bypass; SUI, Stress urinary incontinence; UUI, Urge urinary incontinence.

William Sheridan, Ana Sofia Da Silva and Linda Cardozo, Georgios K Dimitriadis denotes co-first and co-last authors, respectively

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randomized control trials assessing the effect of bariatric surgery on women with obesity-related UI are needed to confirm this study's findings.

#### KEYWORDS

bariatric surgery, behaviour modification, meta-analysis, obesity, systematic review, urinary incontinence, weight loss

## 1 | INTRODUCTION

Obesity is a growing pandemic, with the World Health Organization (WHO) reporting that obesity has nearly tripled worldwide since 1975.<sup>1</sup> In 2016, more than 1.9 billion adults were overweight (body mass index [BMI]  $\geq 25$  kg/m<sup>2</sup>), and of these, over 650 million were obese (BMI  $\geq 30$  kg/m<sup>2</sup>). Obesity is associated with an increased prevalence in multiple non-communicable diseases.<sup>1</sup>

Urinary incontinence (UI) is defined as the involuntary loss of urine<sup>2</sup> and is a common health condition that can significantly affect an individual's quality of life (QoL).<sup>3</sup> Reportedly, approximately 50% of adult women may experience UI,<sup>4</sup> double the prevalence of UI documented in men.<sup>5</sup> This difference in prevalence is due to the structure of the female urinary tract, as well as risk factors such as pregnancy, childbirth, and hysterectomy that can damage the pelvic floor musculature and connective tissue.<sup>5</sup> Obesity is an independent risk factor for urinary storage (leakage) and UI symptoms<sup>6</sup>; such that a 5 points increase of BMI is associated with a 20%-70% increased risk of UI.<sup>6</sup>

Urge urinary incontinence (UUI) is the involuntary leakage of urine associated with urgency whilst stress urinary incontinence (SUI) presents as involuntary leakage with sneezing or coughing.<sup>2</sup> Women with obesity have a 3-fold increased incidence of urge urinary incontinence (UUI) and double the risk of stress urinary incontinence (SUI).<sup>7,8</sup>

In women with obesity, weight loss interventions have been shown to reduce the frequency of UI.<sup>9-11</sup> Currently, clinical guidance bodies such as the National Institute for Health and Care Excellence (NICE) and the European Association of Urology (EAU) recommend life-style intervention as the first-line treatment for women with UI and a BMI  $\geq 30$  kg/m<sup>2</sup>.<sup>12</sup> This encompasses the advice of weight loss through dietary, pharmacological, behavioural therapy interventions, or a combination of these.<sup>12</sup>

Bariatric surgery, including Roux-en-Y gastric bypass (RYBG), Laparoscopic Adjustable Gastric Band (LAGB) and Laparoscopic Vertical Sleeve Gastrectomy (LVSG), is a common intervention to treat morbid obesity (BMI  $\geq 40$  kg/m<sup>2</sup>),<sup>13</sup> but can be an appropriate measure for individuals with a BMI  $\geq 35$  kg/m<sup>2</sup> and related co-morbidities such as diabetes and hypertension. Although behavioural intervention studies have shown to produce statistically significant weight loss in participants,<sup>14</sup> bariatric surgery has proven to lead to significantly greater sustained weight loss in patients with obesity compared to non-surgical alternatives.<sup>15</sup>

### What is known on the subject?

- Obesity is a recognized risk factor for UI
- Weight loss has proven to reduce UI and is currently recommended in the form of behavioural interventions.
- Bariatric surgery is known to lead to greater, sustained weight loss in individuals compared to conservative weight loss methods.

### What does this study add?

- This study aims to clarify the effects of surgically induced weight loss on urinary incontinence and put forward recommendations for further areas of research.

This systematic review and meta-analysis were carried out in order to compare and understand better the effects of surgical and non-surgical weight loss interventions for female obesity-related UI.

## 2 | METHODOLOGY

This protocol was developed according to the Preferred Reporting Items for Systematic review and Meta-Analysis Protocols (PRISMA-P), and followed methods outlined in The Cochrane Handbook for Systematic Reviews of Interventions.<sup>16</sup> This systematic review has been registered with PROSPERO (International Prospective Register of Systematic Reviews) with ID number 222714.

### 2.1 | Search strategy

Two reviewers conducted systematic searches of the following databases: Medical Literature Analysis and Retrieval System Online (MEDLINE), Excerpta Medica (EMBASE), Cochrane Central Register of Controlled Trials (CENTRAL), ClinicalTrials.gov, SCOPUS databases. Our key MeSH (Medical Subject Heading) search terms were; "weight loss surgery" OR "bariatric surgery" OR "metabolic surgery" OR "weight

loss" OR "obesity surgery" OR "obesity treatment" OR "gastric sleeve" OR "sleeve gastrectomy" OR "gastric bypass" OR "gastric band" OR "duodenal switch" OR "biliopancreatic diversion" OR "LSG" OR "LVSG" OR "RYGB" OR "LAGB" OR "diet induced weight loss" OR "lifestyle intervention" OR "obesity medication" OR "weight loss medicine" OR "weight loss drug" OR "weight loss device" AND "urinary incontinence" OR "lower urinary tract symptoms" OR "LUTS" OR "stress urinary incontinence" OR "overactive bladder" OR "detrusor overactivity" OR "Urgency urinary incontinence" OR "Prolapse" OR "POP".

Moreover, reference lists of selected articles and other literature sources were browsed to ensure a comprehensive literature search was completed. None of the database searches filtered results based on year of publication date, and the last search was carried out in September 2020.

## 2.2 | Study selection

Single case reports, expert opinion manuscripts, letters to the editor, commentaries, conference papers, animal studies, meta-analyses, narrative review articles and articles not in English were excluded. Data were only included on adult (18 years or older), non-pregnant women. Articles were included if they examined the effect of any weight loss intervention on UI. No restrictions were made regarding the intervention type, where a study took place, the number of participants or the duration of follow up. Covidence Software was used to manage the study selection process. Publications were initially screened for any duplicates before being assessed independently and in parallel by two reviewers. Any conflicts regarding the inclusion of a study were met with discussion and consensus. If an agreement had not been reached, arbitration by a third reviewer would have been required.

## 2.3 | Data extraction

Data were extracted independently by three reviewers following Cochrane Public Health Group Data Extraction and Assessment Template to construct our own data extraction template that was pilot-tested and systematically used for each article. Data extracted included; study description (eg, title, primary author, publication year, type of study, number of participants, type of weight loss intervention, and follow-up duration), participant demographics (eg, mean age), pre- and post- weight loss intervention anthropometric parameters (mean weight, mean BMI), UI assessment (eg, types of UI assessed, validated questionnaire[s] used), overall diagnosis (urodynamic tests and UI severity rating), quality of life assessments (scores of validated questionnaires). The primary outcomes were the prevalence of total UI, SUI and UI before and after weight loss intervention.

## 2.4 | Quality assessment

Each study was assessed for bias using the Newcastle-Ottawa scale. Studies were evaluated on eight factors, categorized into three

groups: selection (including whether the cohort is representative of the population), comparability (assessed on grounds of study design and the analysis performed) and outcome (ie, the assessment of outcome, follow-up rate and adequacy follow-up period).

Stars were awarded per category, with a maximum of four, two and three stars possible for the 'selection', 'comparability' and 'outcome' categories respectively. By following the guidelines of the Newcastle-Ottawa scale,<sup>17</sup> two reviewers assessed the studies to be of poor (3 stars or less), fair (4-6 stars), or good (7-9 stars) quality.

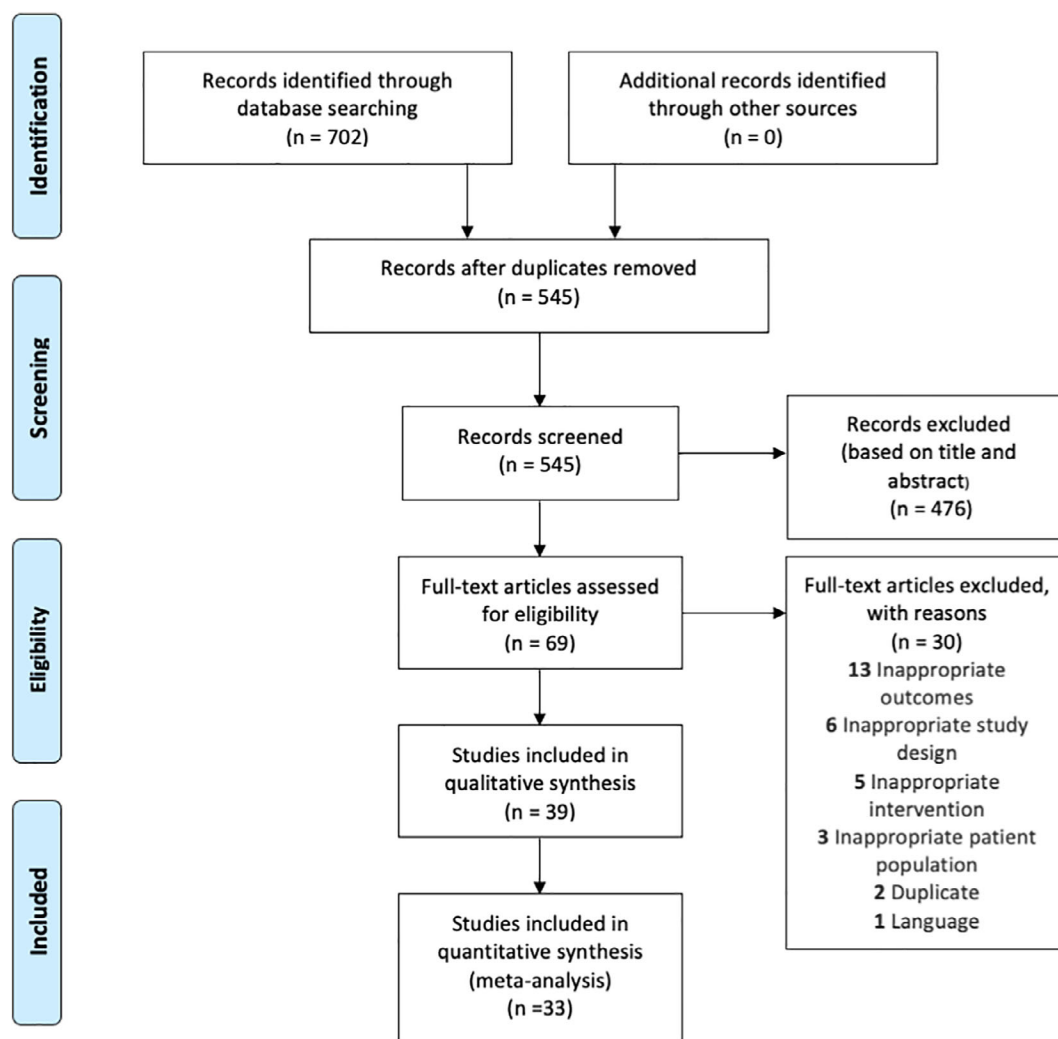
## 2.5 | Data synthesis and statistical analysis

All meta-analytical calculations were performed using MedCalc, the same software was used for generating forest plots. Pooled odds ratios (OR) were calculated with 95% confidence intervals (CI) from the extracted data with count data, while pooled standardized mean differences were calculated from the extracted continuous variables, also with 95% CI. The DerSimonian-Laird random-effects model was used in all calculations. Heterogeneity was assessed using Cochran's Q and I<sup>2</sup> statistics. Subgroup analyses with respect to the type of weight loss intervention were also performed for BMI and weight change differences as well as the count data variables where at least two subgroup data were available. Publication bias was assessed by using Egger's and Begg's tests along with a visual evaluation of the funnel plots when at least ten studies were available.

## 3 | RESULTS

Of the 702 references imported for screening, 157 duplicates were removed, leaving 545 articles to be screened against title and abstract, which resulted in 69 papers progressing to a full-text assessment. Due to one sample of patients from the PRIDE study being reported in 5 different articles<sup>10,11,18-20</sup> only Subak et al.<sup>18</sup> was included in the meta-analysis as this paper reported the outcomes of interest of the present study from the first follow up date. The same decision was made for other articles that reported on one sample of patients, including Treacy et al.<sup>21</sup> and Mazoyer et al.,<sup>22</sup> along with Leshem et al.<sup>22</sup> and Shimonov et al.<sup>23</sup> The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA-P) flow diagram is shown in Figure 1, outlining the outcomes of the screening process.

The 33 studies included in the present study, comprise studies from 12 different countries, amassing 5616 participants, with an age range of 18-78 across all intervention types, with sample size ranging from 10 to 1565. Table 1 (25 surgical intervention studies) and Table 2 (8 behavioural intervention studies) provide an overview of the studies included in this systematic review; including the assessment of outcomes used in the study, a summary of findings for change in total UI, and weekly UI episodes as well as Newcastle-Ottawa scale quality assessment scores.



**FIGURE 1** PRISMA flow diagram of systematic reviews modified from Moher et al.<sup>25</sup>

### 3.1 | Meta-analysis of outcomes

#### 3.1.1 | Changes in BMI and weight

The standardized mean difference (SMD) in BMI pre- and post-intervention, of both intervention types, was calculated from 18 studies as  $-1.948$  (95% CI  $[-2.363, -1.532]$ ,  $p < .001$ ,  $I^2 = 94.10\%$ ), as shown in Figure 2(A). After subgroup analysis, surgical interventions showed a statistically significant SMD with the value of  $-2.120$  (95% CI  $[-2.543, -1.696]$ ,  $p < .001$ ,  $I^2 = 94.07\%$ ), whilst the two non-surgical interventions yielded statistically non-significant difference in pre- and post- BMI (SMD  $-0.402$ , 95% CI  $[-0.880, 0.0761]$ ,  $p = 0.098$ ,  $I^2 = 0.00\%$ ), as shown in Figures 2(B), (C) respectively. For the six studies that reported weight change, SMD for all intervention types was  $-0.803$  (95% CI  $[-1.160, -0.446]$ ,  $p < 0.001$ ,  $I^2 = 83.74\%$ ), see Figure 3. Out of that pool, weight change was reported in two surgical intervention studies (SMD  $-1.615$ , 95% CI  $[-2.684, -0.546]$ ,  $p = .003$ ,  $I^2 = 78.76\%$ ) and in four behavioural intervention studies (SMD  $-0.545$ , 95% CI  $[-0.683, -0.407]$ ,  $p < .001$ ,  $I^2 = 0.00\%$ ).

#### 3.1.2 | Changes in total UI prevalence

A total of 23 studies reported changes in prevalence of UI before and after weight loss interventions. They yielded a significant pooled odds ratio (OR) of  $0.222$  (95% CI  $[0.147, 0.336]$ ,  $p < .001$ ,  $I^2 = 89.76\%$ ), as shown in Figure 4(A). In the subgroup analysis, 18 surgical studies yielded a statistically significant result (OR  $0.209$ , 95% CI  $[0.148, 0.296]$ ,  $p < .001$ ,  $I^2 = 64.96\%$ ), while the result for five non-surgical interventions did not achieve statistical significance (OR  $0.746$ , 95% CI  $[0.545, 1.020]$ ,  $p = .066$ ,  $I^2 = 52.17\%$ ), shown in Figures 4(B), (C) respectively.

#### 3.1.3 | Change in UI prevalence by subtype

Analysis of the total pool of 20 studies that reported prevalence of SUI pre- and post- weight loss intervention, produced a statistically significant pooled OR of  $0.354$  (95% CI  $[0.256, 0.489]$ ,  $p < .001$ ,  $I^2 = 82.38\%$ ), Figure 5(A). The subgroup analysis of 17 surgical

TABLE 1 Characteristics of Surgical Intervention Studies

Study	Country	Type of Surgery	Study design and primary outcome	Follow-up (Months)	Sample size (n)	Mean (SD) BMI Pre- and Post-Intervention (kg/m <sup>2</sup> )	Mean (SD) Weight Pre- and Post-Intervention (kg)	Assessment of outcome	Change in Urinary Incontinence Prevalence and/or No. of Episodes	NOS Star Award and Assessment of Quality
Castro 2012 <sup>26</sup>	Brazil	Not Specified.	Prospective Cohort study on the probability of UI before and after surgery	12	17	49.96 (5.77) to 29.97 (3.48)		Clinical interview, questionnaires on UI, KHQ, Modified Oxford Scale, perineometry, physical exam	At baseline, 17/17 incontinent women. Post-operatively, 5/17 were incontinent. 12 women became continent. $p < 0.001$ .	8- Good
Olivera 2012 <sup>27</sup>	United States	RYGB, LAGB, LVSG (not specified)	Prospective cohort study on the impact on UI	37.8	36	45.76 (6.48) to 31.55 $p < 0.0001$		PFIQ, PISQ-12, FSFI	No prevalence data	7- Good
Kim 2017 <sup>28</sup>	Korea	RYGB (57)	Prospective Cohort study on benefit of surgery on LUTS (UI).	12	57	37.5 (5.9) to 28 (4.9) $p < 0.001$		IPSS, OABSS, PPBC, Sandvik questionnaire, BDI	At baseline, 40.74% were incontinent at Post-operatively, 18.51% had incontinence.	7- Good
Romero Talamás 2016 <sup>29</sup>	United States	RYGB (65), LVSG (5), LAGB (2)	Prospective cohort study assessing prevalence of UI, SUI, UII and other PFDs.	12	72	47.5 (9.4) to 32.7 (8.1) $p < 0.001$		PFDI-20, PFIQ-7, PISQ-12, screening questions, urodynamics, POP-Q	SUI was identified in 60 (83.3%) patients at baseline and 32 (44.4%) at follow-up, $p = 0.001$ . UII prevalence at baseline and follow up was 54, and 27 respectively, $p < 0.001$ . Urodynamic evaluation confirmed decreased in SUI prevalence after surgery (from 76.9% to 30.8%, $P = 0.01$ ). No confirmation in UII.	7- Good
Wasserberg 2009 <sup>30</sup>	United States	RYGB (21), Duodenal switch (22), LVSG (3)	Prospective Cohort study on impact on PFD (mainly UI).	18.6	46	45 to 75	128 to 79	PFDI-20, PFIQ-7	At baseline, 71% had incontinence. Post-operatively, incontinence decreased to 39% ( $P = 0.003$ )	5- Fair
Whitcomb 2012 <sup>31</sup>	United States	LVSG (3), LAGB (95)	Prospective cohort study on SUI and UII prevalence.	12	69	39.7 (6.2) to 34 (5.6)		EPIQ, PISQ, FSFI, SF-36	At baseline: Prevalence of SUI was 22/69 (32 %). At 6 months follow up, this decreased to 10/69 (15 %) ( $p = 0.006$ ) and at 12 months, was 14/69 (20 %) at ( $p = 0.027$ )	6- Fair
Knepler 2016 <sup>32</sup>	France	RYGB (67), LVSG (2)	Prospective cohort study on UI incidence.	11.3	70	44.5 (6.31) to 31.83 (5.83)		PFDI 20	UI incidence reduced from 57/70 (81%) at baseline to 41/70 (59%) post-intervention ( $P = 0.003$ ). The number of continent patients increased from 13 at baseline, to 29 at follow up, ( $P = 0.003$ )	5- Fair
Bump 1992 <sup>33</sup>	United States	RYGB (13)	Prospective cohort study on impact on UI following bariatric surgery.	14.5		49.4 (7.9) to 33.1 (6.7) $p = 0.000001$	131.5 (19.9) to 88.1 (17)	Urogynaecologic history, genitourinary physical and neurologic examination, Voiding diary, fluid loss quantitation test, urodynamic evaluation	UI prevalence was 12/13 at baseline, and 3/13 post-surgery ( $p = 0.004$ ). Number of incontinence episodes/ week after; 13.4 (SD 2.9), and after weight loss; 0.9 (SD 0.5), $p = 0.001$ . Number of incontinence pads used/ day: 2.0 (SD 0.30) decreased to 0.08 (SD 0.08), $p = 0.00008$	7- Good

(Continues)

TABLE 1 (Continued)

Study	Country	Type of Surgery	Study design and primary outcome	Follow-up (Months)	Sample size (n)	Mean (SD) BMI Pre- and Post-Intervention (kg/m <sup>2</sup> )	Mean (SD) Weight Pre- and Post-Intervention (kg)	Assessment of outcome	Change in Urinary Incontinence Prevalence and/or No. of Episodes	NOS Star Award and Assessment of Quality
Daucher 2010 <sup>34</sup>	United States	RYGB (34)	Prospective Cohort study on the impact on urinary function and other PFDs.	6	34	46 (6) to 33 (6)		PFDI, PFIQ, PISQ-12, POP-Q, 3-day bladder diary	Urodynamic evaluation: 2/3 of subjects resolved SUI, 1/2 had resolution of detrusor instability, 1 had MUI resolved. Not statistically significant results as a result of the small sample size.	8- Good
Cuicchi 2013 <sup>35</sup>	Italy	RYGB (87)	Prospective cohort study assessing change in prevalence of UI.	12	87	34 (6.7) to 30 (5.9)		ICIQ-SF, PFDI, PFIQ-7, POPDI-6	At baseline: 58.6% were incontinent. Post-operatively, prevalence decreased to 17.2% and 9.2% at 6- and 12- months respectively (p < 0.0001). At 12 months, 43 (84.3%) of 51 patients became continent. The remaining, 4 had improved UI, 2 had no change, and 2 reported worsening.	7- Good
Ranasinghe 2011 <sup>36</sup>	Australia	LAGB	Retrospective study on the change in UI (and subtypes) symptoms.	120	143	43.5 (6.65) to 35.5 (6.8) p<0.0001	118.3 (18.5) to 96.7 (18.48)	ICIQ-SF, IPSS	At baseline, SUI prevalence: 38/97 and UI prevalence: 11/97. Post-operatively, 11 women became continent. SUI was 27/97 (p= 0.0164) UI prevalence worsened; 17/97 (p= 0.1088)	4- Fair
Fujisaki 2019 <sup>37</sup>	Japan	RYGB (8), LVSG (30)	Prospective Cohort study on UI incidence	12	55	Not reported		Pad usage, ICIQ-UI-SF,	SUI prevalence: At baseline = 35, post-surgery = 11 (p = 0.0001). UI prevalence: At baseline = 11 post-surgery = 4 (p= ns)	4- Fair
Laungani 2009 <sup>38</sup>	United States	Gastric bypass	Prospective cohort study on impact on UI symptoms following surgery.	12	58	48 (7) to 32 (4)		ICIQ-SF	At baseline, 0/58 patients never leaked. At 12 months, 16/25 participants had UI resolved and never leaked (p<0.001). The number of patients with resolved or improved UI symptoms was 92% (23/25) at follow up. SUI baseline: 46/58 (79%), follow-up: 05/25 (p<0.001)  UI baseline: 31/58 (53%), follow up: 7/25 (28%) (p = 0.03)	6- Fair



TABLE 1 (Continued)

Study	Country	Type of Surgery	Study design and primary outcome	Follow-up (Months)	Sample size (n)	Mean (SD) BMI Pre- and Post-Intervention (kg/m <sup>2</sup> )	Mean (SD) Weight Pre- and Post-Intervention (kg)	Assessment of outcome	Change in Urinary Incontinence Prevalence and/or No. of Episodes	NOS Star Award and Assessment of Quality
Shimonov 2017 <sup>24</sup>	Israel	LVSG	Prospective cohort study on UI prevalence after surgery.	6	77	42.2 to 33		ICIQ-UI-SF, BFLUTSSF, PFDI-20, PISQ-12	Total UI prevalence at baseline: 29 (37.7%) Total UI prevalence at follow-up: 14. Change: 15 (51.7%) The number of UI episodes decreased by 47% in the intervention group, compared with 28% in the control group.	6- Fair
Scozzari 2013 <sup>39</sup>	Italy	RYGB (18), LVSG (2), LAGB (12)	Prospective cohort study on UI incidence following surgery.	15.6	32	46.3 (6.3) to 31.3 p<0.0001	122 to 83.2	PFDI-20	At baseline, Total UI prevalence: 59.4% At follow-up: 50% (p = ns) SUI: no significant decrease UUI: Baseline: 14 (43.8%) Follow-up: 5 (15.6%) (p=0.029)	8- Good
Study	Country	Type of Surgery	Study design and primary outcome	Follow-up (Months)	Sample size (n)	Mean (SD) BMI Pre- and Post-Intervention (kg/m <sup>2</sup> )	% Weight loss	Assessment of outcome	Change in Urinary Incontinence Prevalence and/or No. of Episodes	NOS Star Award and Assessment of Quality
Durigon Keller 2019 <sup>40</sup>	Brazil	RYGB (83)	Prospective Cohort study on weight loss impact on UI severity	12	26	44.96 (6.49) to 29.98 (6.23) p<0.0001		ICIQ-SF, KHQ	At baseline: Total UI prevalence: 26 (100%); Continent 0, mild 7, moderate 12, severe 6, very severe 1. Post-operative UI prevalence: 14; continent 15, mild 6, moderate 3, severe 2.	7- Good
Bulbul 2017 <sup>41</sup>	Turkey	LVSG (120)	Prospective Cohort study on impact on UI, SUI, UUI.	6	120	46.17 (5.35) to 31.6 (4.37)		ICIQ-SF, KHQ	UI prevalence at baseline: 72 (SUI-18, UUI-23, MUI-31) Total UI prevalence at follow-up: 44 (SUI-7, UUI-14, MUI-23).	7- Good
Kuruba 2007 <sup>42</sup>	United States	RYGB (42), LAGB (3)	Prospective cohort study on the impact of bariatric surgery on UI severity.	12	45		EBWL: 64% (range 19 to 91%)	UI severity index by Sandvik	At Baseline: 44 women (100%) Preoperatively, the patients reported slight (4%), moderate (47%), or severe (49%) urinary incontinence. At follow up: - 50% of the patients had resolution of urinary incontinence, 18% had slight, 18% had moderate, 13% had severe symptoms 95% reported subjective improvement or resolution of UI, 5% reported unresolved UI	5- Fair
Mazoyer 2019 <sup>22</sup>	France	RYGB (30), LVSG (24)	Prospective Monocentric Pilot Study on the incidence of urinary symptoms.	12	54		TWL: 33% (Range 9-51)	USP, PFDI-20 (POPDI, CRADI, UDI)	At baseline 32 (59%) had UI, UDI mean score decreased from 21.8 (SD 19.9) before surgery to 6.5 (SD 9.2) post-operatively (p < 0.0001). Weight loss was associated with a significant improvement in UI (p < 0.0001).	7- Good

(Continues)

TABLE 1 (Continued)

Study	Country	Type of Surgery	Study design and primary outcome	Follow-up (Months)	Sample size (n)	Mean (SD) BMI Pre- and Post-Intervention (kg/m <sup>2</sup> )	% Weight loss	Assessment of outcome	Change in Urinary Incontinence Prevalence and/or No. of Episodes	NOS Star Award and Assessment of Quality
Subak 2015 <sup>43</sup>	United States	RYGB (1111), Duodena I switch (12), LVSG (33), LAGB (387)	Prospective Cohort study on the change in UI prevalence (after weight loss).	12	1565		-29.5%	Validated participant reported UIQ	Baseline total UI prevalence: 772 Follow-up total UI prevalence: 250 Breakdown by subtype: SUI at baseline: 646, Post-operatively: 188 UII at baseline: 505, Post-operatively: 165	7- Good
Burgio 2007 <sup>44</sup>	United States	RYGB (101)	Prospective cohort study on the prevalence of UI following bariatric surgery.	6 and 12	101	Mean (SD) BMI Pre- and Post-Intervention (kg/m <sup>2</sup> ) 48.9 (7.2) to 30.2 (5.7)		Assessment of outcome MESA, UDI, HQ	At baseline: Total UI prevalence: 66.7%. At follow-up: Prevalence decreased to 37% at 12 months (56% reduction), p <0.001 (CI 95% 18.6-40.0). Women with UI who lost at least 18 BMI points, 71% had regained urinary continence 12 months after surgery. SUI prevalence at baseline was 59.8% and decreased to 31.5% at 12 months (p <0.001) (CI% 17.2-39.3). UII prevalence at baseline was 35.9% and decreased to 15.2% at 12 months, (p <0.001) (CI 95% 10.4-30.9). MUJ prevalence at baseline was 31.6% and decreased to 9.9% at 12 months, (p<0.001) (CI 95% 11.0-30.7).	6- Fair
O'Boyle 2016 <sup>45</sup>	Ireland	RYGB (57), LVSG (24), LAGB (1)	Prospective cohort study on prevalence of UI.	15	82	50 (6.3) to 34 (6.8)		ICIQ-SF	At baseline: 82(100%) women had UI. 75% of patients complained of moderate to very severe incontinence. At follow up: 55. 83% patients reported reduced symptom severity. 33% reported complete symptom resolution. 37% had moderate to very severe incontinence.	6- Fair
AttSaid 2017 <sup>46</sup>	France	LVSG and RYGB	Prospective Cohort study on prevalence of SUI and UII.	12	83	43.7 (7.3) to 30.2 (7)		USP, ICIQ, - SF Wexner scale, QOL	Baseline prevalence: SUI - 49.4%, OAB - 43.3% Follow-up prevalence: SUI- 21.7%, OAB: 7.3% No correlation between the degree of weight loss and improvement of SUI (r = 0.007, p = 0.65) and UII (r = 0.05, p = 0.64).	7- Good



TABLE 1 (Continued)

Study	Country	Type of Surgery	Study design and primary outcome	Follow-up (Months)	Sample size (n)	Mean (SD) BMI Pre- and Post-Intervention (kg/m <sup>2</sup> )	Assessment of outcome	Change in Urinary Incontinence Prevalence and/or No. of Episodes	NOS Star Award and Assessment of Quality
Anglim <sup>47</sup> 2018	Ireland	RYGB (40), LVSG (21)	Prospective Cohort study on impact on UI and cure rate.	12	61	51 (7) to 33 (9)	ICIQ-SF	At baseline: Total UI prevalence at baseline: 61  At follow-up: 27 SUI change in prevalence: 22 to 9 UUI (OAB) change: 13 to 5 MUI change: 27 to 13	6- Fair
Leshem <sup>48</sup> 2018	Israel	RYGB (7), LAGB (94)	Prospective Cohort study on UI prevalence.	24	101	41.6 (4.6) to 27.5 (4.4)	ICIQ-SF, BFLUTS, PFDI-20, PISQ-12	At baseline: 43 women had UI, 27 (63%) had SUI, 12 (28%) had MUI and two (4.5%) had UUI. At follow-up, prevalence of UI was 18. 13 had SUI, 2 had MUI, 3 had UUI.	5- Fair

Abbreviations: RYGB, Roux-en-Y Gastric Bypass; LAGB, Laparoscopic Adjustable Gastric Band; LVSG, Laparoscopic Vertical Sleeve Gastrectomy; BMI, Body Mass Index; EBWL, Excess Body Weight Loss; TWL, Total Weight Loss; KHQ, Kings Health Questionnaire; PFIQ-7, Pelvic floor Impact Questionnaire; PISQ-12, Pelvic Organ Prolapse/Urinary Incontinence Sexual Questionnaire; FSFI, Female Sexual Function Index; IPSS, International Prostate Symptom Score; OABSS, Overactive Bladder Symptom Score; PPBC, Patient perception of bladder condition; BDI, Beck Depression Inventory; PFDI-20, Pelvic Floor Distress Inventory; POP-Q, Pelvic Organ Prolapse Qualification; EPIQ, Epidemiology of Prolapse and Incontinence Questionnaire; SF-36, Short-Form 36 Health Survey; POPDI-6, Pelvic Organ Prolapse Distress Inventory; UDI, Urogenital Distress Inventory; ICIQ-SF, International Consultation on Incontinence Questionnaire Short Form; MESA, The Medical, Epidemiological, and Social Aspects of Ageing Questionnaire; CRADI, Colorectal-anal Distress Inventory; USP, Urinary Symptoms Profile; UI, Urinary; SUI, Stress Urinary Incontinence; UUI, Urge Urinary Incontinence; BFLUTS, Bristol Female Lower Urinary Tract Symptoms; PGI-I, Patient Global Impression of Improvement; PFMS, Pelvic Floor Muscle Strength.

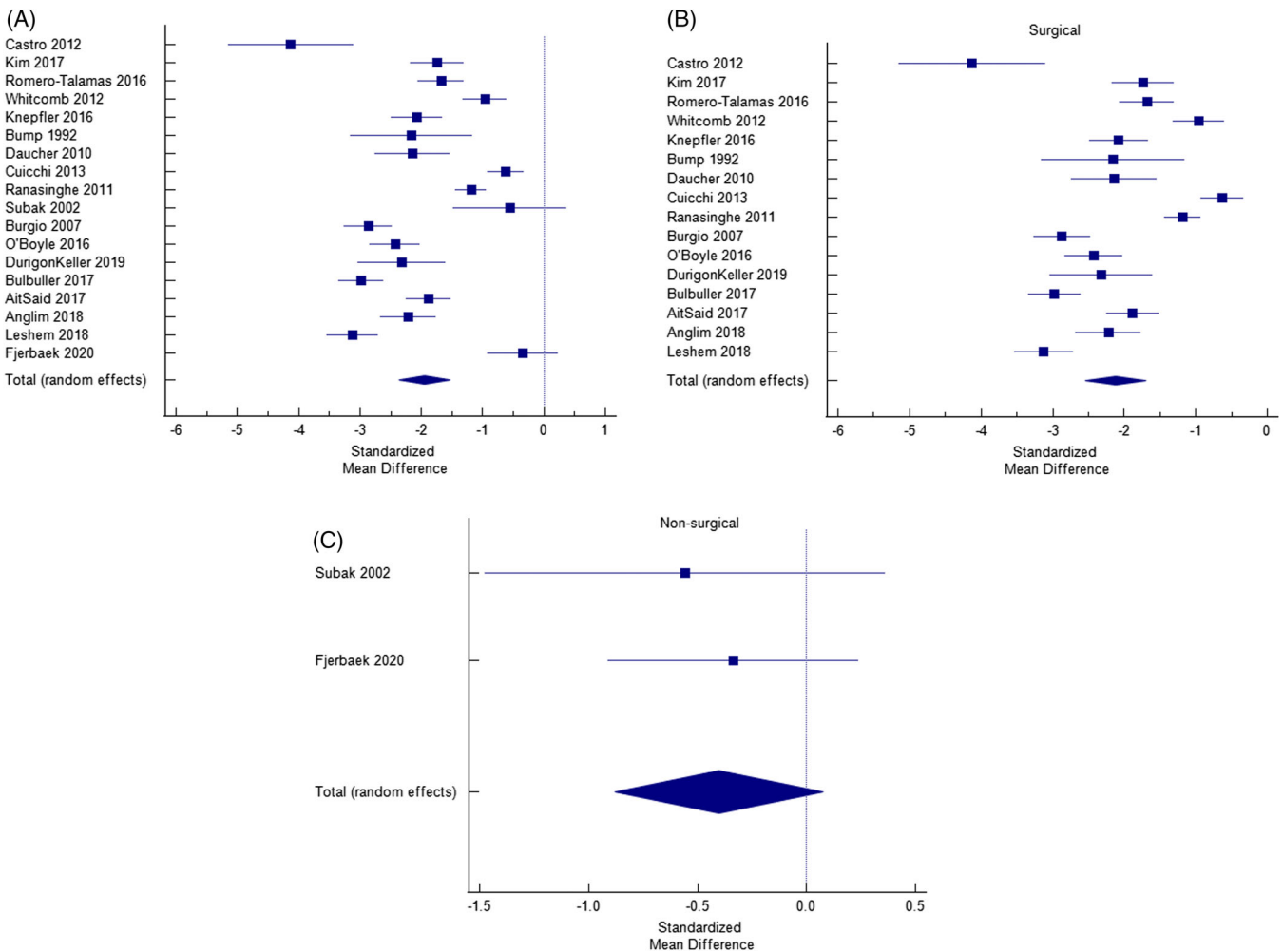
TABLE 2 Characteristics of Behavioural Intervention studies

Study	Country	Description of intervention	Study design and primary outcome	Follow-up (Months)	Sample size (n)	Mean (SD) Weight Pre- and Post-Intervention (kg)	Assessment of outcome	Change in Urinary Incontinence Prevalence and/or No. of Episodes	NOS Star Award and Assessment of Quality
Subak 2005 <sup>49</sup>	United States	Behavioural modification: Intensive group-based medical and behavioural weight loss program. Low-calorie liquid diet (800 kcal per day or less), increased exercise (60 mins daily), taught standard cognitive & behavioural skills. Weekly group sessions led by a nutritionist, exercise physiologist or behavioural therapist.	Randomised controlled trial assessing change in weekly UI episodes.	6	19	99 to 84	A 7-day voiding diary, HQ, UDI, SF-36, Urodynamic studies	Median (IQR) Episodes per week: Total UI: At baseline: 21 (11-33); At follow up: 4 (2-28); % improvement: 60% (30-89); p = 0.0005. SUI: At baseline: 8 (2-13); At follow up: 0 (0-4); % improvement: 92% (66-100), p = 0.003. UUI: At baseline: 8 (4-20); At follow up: 2 (0-10); % improvement: 70% (16-100), p = 0.03 At follow up: 7 (18%) of women were 100% improved, 14 (35%) were at least 75% improved and 20 (50%) were at least 50% improved in weekly incontinence frequency. 50% reduction in incontinence (p 0.001) was observed in 58% (21 of 36) of women who achieved >5% weight loss and 25% (1 of 4) who achieved <5% weight loss.	9- Good
Phelan 2012 <sup>49</sup>	United States	The Look AHEAD trial promoted weight loss of at least 7% weight loss by the first year, through a low calorie, low fat, and portion-controlled diet as well as weekly exercise (175 minutes).	Randomised controlled trial on the change of weekly UI episodes.	12	1385	ILI -77 (7.0); Control 0.7(5.0)	Validated self-report questions	Weight loss intervention was associated with a 20% reduction in the odds of having UI (OR 0.80, 95% CI 0.65-0.98, p = 0.03), compared with control group. At follow-up, SUI prevalence was less in ILI group (10.5%) than in the control group (12.8%), (p = 0.07). Intervention decreased the odds of having SUI by 27% (OR 0.73, 95% CI 0.55- 0.96), p = 0.03 Total UI prevalence at follow-up: intervention group (25.3%) was lower than the control group (28.6%) (p = 0.05). No significant effect between treatment groups (intervention & control) was seen on the 1-year prevalence of urgency UI (p=0.42).	9- Good
Subak 2009 <sup>6</sup>	United States	Behavioural modification: PRIDE Program modelled on Look AHEAD. Calorie and fat restriction of 1200 to 1800 kcal daily, depending on initial weight, with less than 30% of calories from fat. Encouraged to increase exercise to 200 mins per week. Behavioural skills, including self-monitoring, stimulus control, and problem-solving, were emphasised.	Randomised controlled trial on the percentage change in number of incontinence episodes.	6	226	98.17 (17) to 90 (17)	7-day diary of voiding	At baseline, SUI was prevalent in 44 women and UUI prevalence was 104. At follow-up, 32 women (27% reduction) had SUI, and 94 (19% reduction) had UUI. 41% of women in intervention group had >70% reduction in any UI episodes, compared to 22% of control group (p<0.001) Mean No. of UI episodes per week: Total UI: At baseline: 24 (SD 18); At follow-up: 13 (SD 15); % change: -47.4% (95% CI, -54 to -40%), p = 0.01 SUI: At baseline: 9 (SD 11); At follow-up: 4 (SD 7); % change: -57.6% (95% CI, -67 to -46), p=0.02 UUI: At baseline: 14 (SD 14), UUI: WL: 8 (SD 11); % change: -42% (95% CI, -51 to -32), p=0.14	8- Good
Brown 2006 <sup>50</sup>	United States	Behavioural Modification: Included 3 groups: ILI, Metformin at 850 mg 2x daily, or placebo twice daily. Through a low-fat diet and moderate-intensity physical activity for at least 150 min each week, the ILI aimed to lose a minimum 7% of initial body weight.	Randomised controlled trial on the change in UI prevalence as a result of lifestyle intervention	36	660	-3.4 (8.2)	Self-reported questionnaire	Prevalence of weekly incontinence episodes at baseline was 48.1%. At follow-up, reduced to 38.3% (p<0.001). Intensive lifestyle intervention was associated with a 20% reduction in the odds (OR 0.80 [95% CI 0.64-1.01]) of weekly SUI episodes compared with placebo.	8- Good

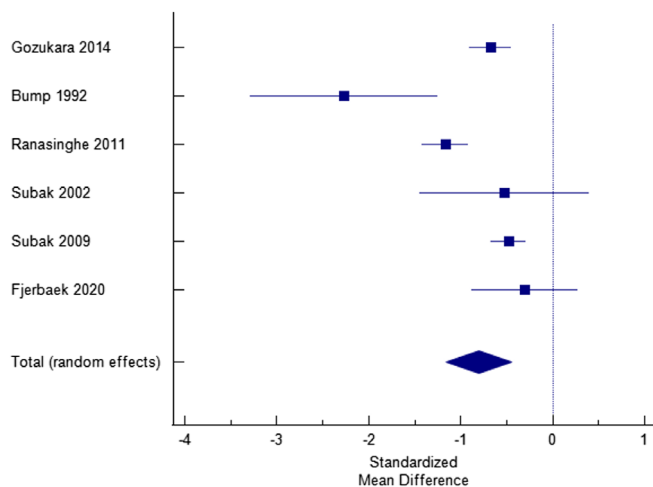
TABLE 2 (Continued)

Study	Country	Description of intervention	Study design and primary outcome	Follow-up (Months)	Sample size (n)	Mean (SD) BMI Pre- and Post-Intervention (kg/m <sup>2</sup> )	Mean (SD) Weight Pre- and Post-Intervention (kg)	Assessment of outcome	Change in Urinary Incontinence Prevalence and/or No. of Episodes	NOS Star Award and Assessment of Quality
Auwad 2008 <sup>51</sup>	UK	Behavioural modification: All participants were offered a commercially run programme of diet and exercise. Anti-obesity medication, Orlistat, was offered to those who did not lose 5% of starting weight within 9 months.	Prospective Cohort study on the incidence of UI episodes.	20	42	36.2 to 31.9		24-h pad test, KHQ, Perineometry, Modified Oxford score.	At Baseline: 6 had mild incontinence, 26 had moderate incontinence and ten had severe incontinence (before weight loss At Follow-up: 21 had mild leakage, 15 had moderate leakage, and only four had severe leakage (p < 0.001) Mean 24hr pad test results (by weight): 38.7 5g at baseline; 18.5g at follow up (p < 0.001). Objective urodynamic baseline UI prevalence: SUJ-20, UUI-8, MUI- 8. At follow-up, 8 women (40%) with an initial diagnosis of SUJ had become continent.	8- Good
Fierbaek 2020 <sup>52</sup>	Denmark	Behavioural modification: Four individual dietary counselling session, (one group received 5 sessions), two training session per week for 12 weeks.	Prospective Cohort study assessing UI impact on quality of life after weight loss.	9	24	32.7 (4.54) to 31.2 (4.23) p<0.0001	89.29 (12.58) to 85.5 (12.31)	ICIQ-SF, PGI-I, 24-hour pad test, PFMS	Mean 24hr pad test results (by weight): 33.11g at baseline; 14.79g at follow up (p =0.180)	6- Fair
Subak 2002 <sup>53</sup>	United States	Behavioural modification: Weight loss program - low calorie liquid diet or reduced-calorie solid diet and exercise.	Prospective cohort study on change in incontinence frequency	3	10	38 (10) to 33 (7) P=0.03	106 (32) to 91 (22)	7-day urinary diary	At Baseline: UI episodes per week: 13(SD 10). At Follow-up: UI episodes per week: 8 (SD 10), with a median reduction of 6 episodes per week. Pad use at baseline was 8 and following weight loss there was a 60% decrease in pad use (p <0.04).	7- Good
Gozukara 2014 <sup>54</sup>	Turkey	Behavioural modification: Aimed to produce an average loss of >7% within 6 months Restricted calorie and fat diet (1,200-1,800 kcal daily).	Randomised controlled trial on change in number of UI episodes.	6	163		85.1 (9.7) to 78.3 (10.4)	3- day voiding diary, PFDI, POP-Q, UDI, POPDI, CRADI	At baseline: SUJ episodes per 3 days: 7.96 UUI episodes per 3 days: 2.85 At follow up: SUJ episodes per 3 days: 3.11 UUI episodes per 3 days: 1.08 No change in SUJ and UUI episodes in the control group.	9- Good

Abbreviations: AHEAD, Action for Health in Diabetes; DSE, Diabetes Support and Education; ILI, Intensive Lifestyle Intervention; PRIDE, Program to Reduce Incontinence by Diet and Exercise.



**FIGURE 2** Forest plot of standardized mean difference in pre- and post- BMI from all interventions (A), Surgical intervention studies (B) and behavioural (non-surgical) intervention studies (C)

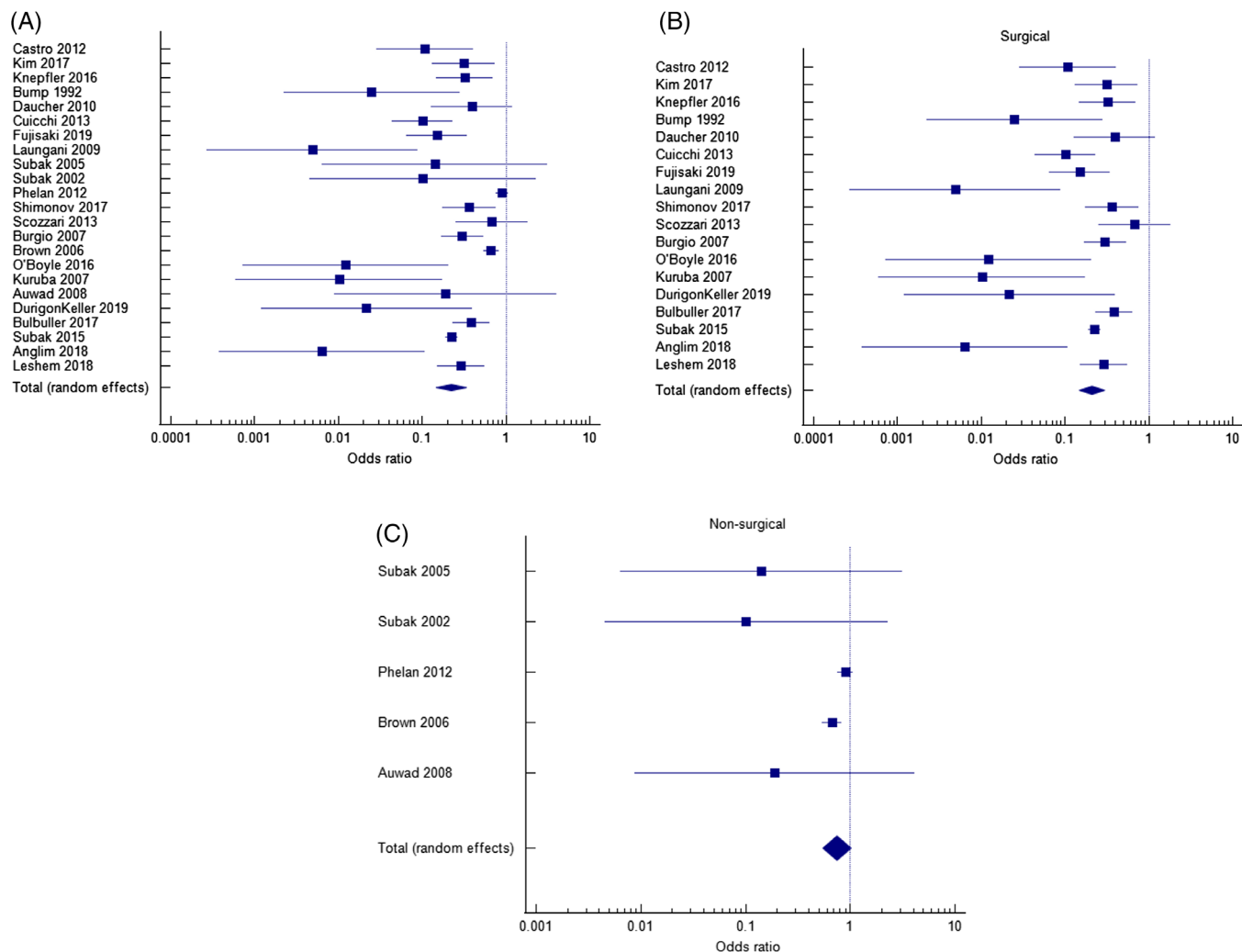


**FIGURE 3** Forest plot of standardized mean difference in pre- and post- weight change

interventions for changes in prevalence of SUI was statistically significant for both surgical interventions (OR 0.312, 95% CI [0.235, 0.414],  $p < .001$ ,  $I^2 = 61.68\%$ ) and non-surgical interventions (OR 0.754, 95% CI [0.614, 0.926],  $p = .007$ ,  $I^2 = 0.00\%$ ), shown in Figures 5(B), (C) respectively.

The calculated OR for UII with regard to any weight loss intervention was statistically significant (OR 0.437, 95% CI [0.295, 0.649],  $p = .001$ ,  $I^2 = 77.39\%$ ), shown in Figure 6(A). When considering UII changes by intervention type; meta-analysis of the 15 surgical intervention studies showed a statistically significant reduction in UII prevalence (OR 0.378, 95% CI [0.259, 0.552],  $p < .001$ ,  $I^2 = 65.49\%$ ), shown in Figure 6(B), whilst the two non-surgical ones did not (OR 0.943, 95% CI [0.661, 1.344],  $p = .745$ ,  $I^2 = 0.00\%$ ), shown in Figure 6(C).

Meanwhile combined analysis of six studies demonstrated changes in mixed UI prevalence (OR 0.330, 95% CI [0.189, 0.576],  $p < .001$ ,  $I^2 = 59.10\%$ ), all of which were surgical interventions, shown in Figure 7.



**FIGURE 4** Forest plot of OR values of UI prevalence from all interventions (A), Surgical intervention studies (B) and behavioural (non-surgical) intervention studies (C)

### 3.1.4 | Change in questionnaire scores

Several questionnaires were used to assess improvement of urinary function and QoL in the observed studies. Statistically significant results were obtained while calculating SMDs in all questionnaires of interest. For Pelvic Floor Distress Inventory (PFDI-20), the calculated SMD was  $-0.774$  (95% CI  $[-1.236, -0.312]$ ,  $p = .001$ ,  $I^2 = 93.42\%$ ), shown in Figure 8(A). For International Consultation on Incontinence Questionnaire Short Form (ICIQ-UI-SF), SMD was  $-1.110$  (95% CI  $[-1.497, -0.723]$ ,  $p < .001$ ,  $I^2 = 89.68\%$ ), as shown in Figure 8(B). Finally, for Urinary Distress Inventory (UDI), SMD was  $-0.742$  (95% CI  $[-0.911, -0.572]$ ,  $p < .001$ ,  $I^2 = 40.10\%$ ), shown in Figure 8(C).

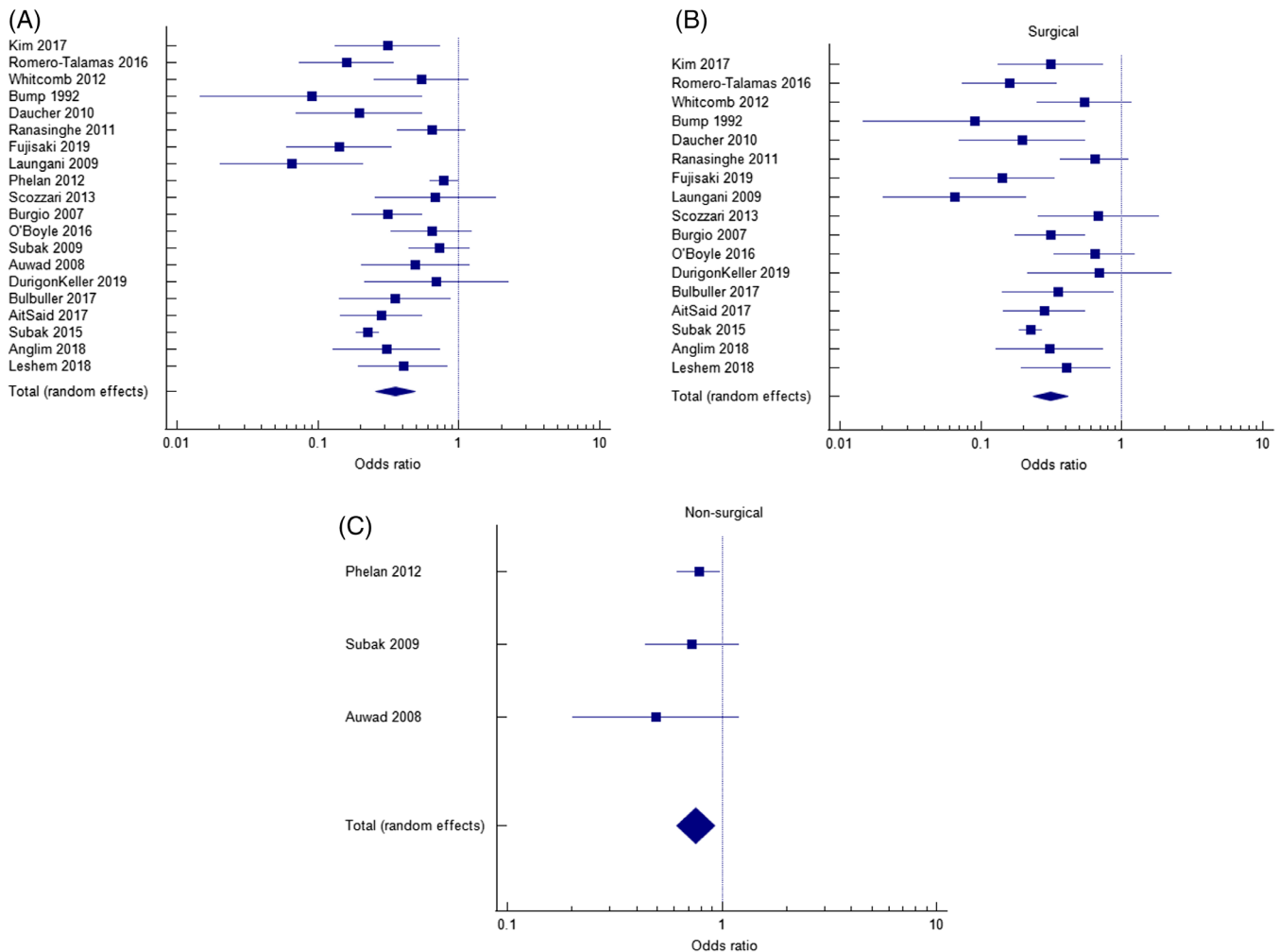
## 4 | DISCUSSION

The results of this meta-analysis demonstrate that the prevalence of UI before and after weight loss was significantly reduced (OR 0.222,

95% CI  $[0.147, 0.336]$ ). Subgroup analysis of interventions showed surgical weight loss interventions were associated with greater reductions in the odds of patients experiencing UI (OR 0.209, 95% CI  $[0.148, 0.296]$ ) compared with behavioural intervention studies (OR 0.746, 95% CI  $[0.545, 1.020]$ ).

SUI and UUI prevalence also significantly improved after weight loss (OR 0.354, 95% CI  $[0.256, 0.489]$  and OR 0.437, 95% CI  $[0.295, 0.649]$ , respectively). In addition, comparison of interventions showed patients who underwent weight loss through surgical means, experienced significantly decreased odds ratios in both SUI and UUI prevalence at follow-up (OR 0.312, 95% CI  $[0.235, 0.414]$  and OR 0.378, 95% CI  $[0.259, 0.552]$  respectively), whilst behavioural interventions showed a weaker improvement in SUI (OR 0.754, 95% CI  $[0.614, 0.926]$ ) and a non-significant improvement in UUI (OR 0.943, 95% CI  $[0.661, 1.344]$ ).

The evidence from this meta-analysis showed the studies where bariatric surgery had been performed led to greater reductions in BMI (SMD  $-2.120$ , 95% CI  $[-2.543, -1.696]$ ), which may explain the greater improvement in UI, SUI, and UUI prevalence, compared with



**FIGURE 5** Forest plot of OR values of stress urinary incontinence prevalence from all interventions (A), Surgical intervention studies (B) and behavioural (non-surgical) intervention studies (C)

behavioural weight loss interventions that demonstrated less significant reductions in BMI (SMD -0.402, 95% CI [-0.880, 0.0761]).

The Patient Reported Outcome Questionnaires included in this study were PFDI-20, ICIQ-UI-SF, and UDI, commonly used to assess UI, the severity of incontinence symptoms and their effects on quality of life. Pooled analysis of these scores showed statistically significant reductions in standardized mean differences of the scores from baseline to follow-up, suggesting that weight loss was associated with a significant improvement in UI prevalence and patient's quality of life.

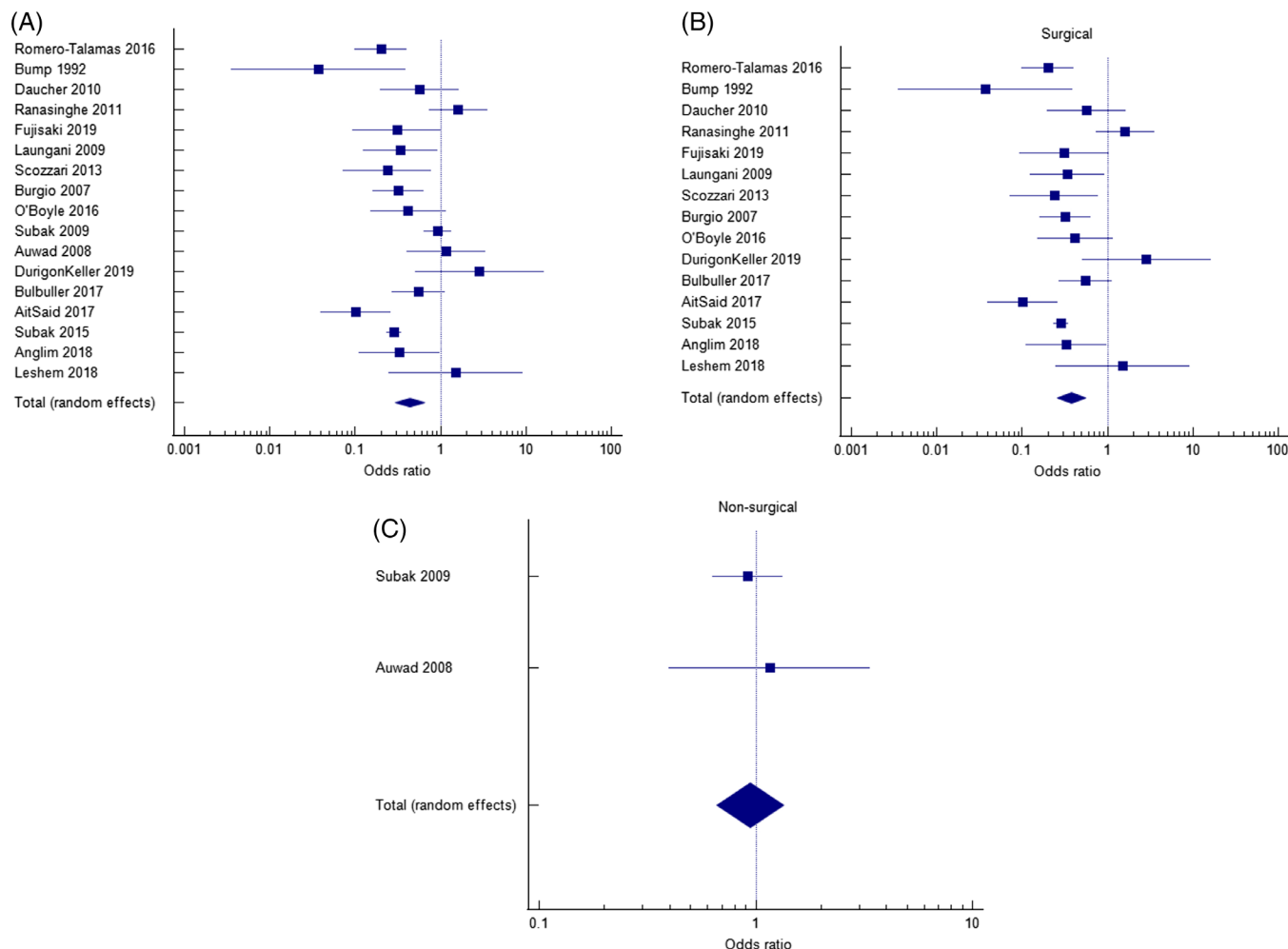
Whilst the underlying pathophysiology of UI is multifactorial and its aetiology not completely known, obesity is a recognized risk factor,<sup>6,33,55,56</sup> and a dose-response relationship between increased weight and UI incidence has been observed.<sup>7</sup> A study by Noblet et al. showed a strong correlation between BMI, intra-abdominal pressure and intravesical (bladder) pressure, with a Pearson correlation coefficient value of 0.76 and 0.71, respectively, both  $p < .0001$ .<sup>57</sup> It was hypothesised that this increased intra-abdominal pressure increases stress on pelvic floor organs and supporting structures, and that such stress is responsible for the symptoms presented in SUI.<sup>57</sup> Similarly,

an increase in abdominal pressure as a result of increased abdominal adiposity, may also be responsible for detrusor instability (detrusor muscle overactivity) which can cause the symptoms of urgency that present in UI.<sup>9</sup>

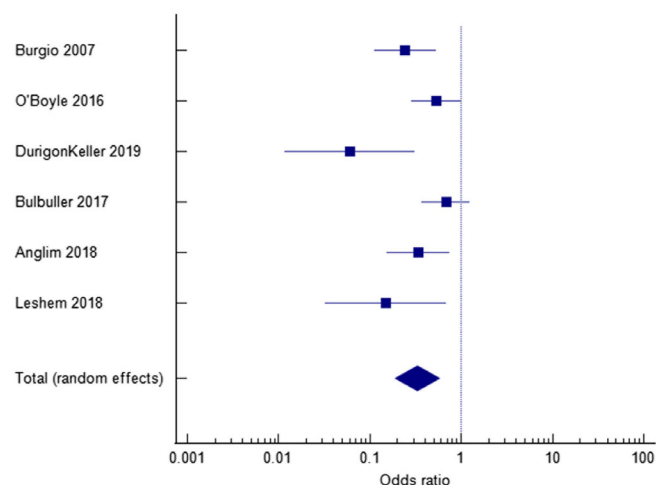
A cohort study examining the effects of surgical weight loss interventions highlighted that reduced abdominal adiposity was associated with significant decreases in urinary bladder pressure.<sup>58</sup> The effects of reduced bladder pressure and SUI were observed by Bump et al., in whose study, patients' intravesical pressure readings were significantly improved at follow-up and associated with a resolution in SUI in 7 of the 10 patients who complained of SUI at baseline.<sup>33</sup>

Traditional management of UI can include bladder retraining and lifestyle changes, which typically advise avoidance of bladder irritants and reducing overall fluid intake.<sup>59</sup> Both carbonated drinks and caffeinated beverages are considered to be bladder irritants.<sup>60,61</sup> Following bariatric surgery, patients are advised to avoid bladder irritants and drinking fluids with meals.<sup>62</sup> In a similar way, the dietary changes promoted in behavioural studies involve reduced calorie intake, which is likely to be associated with reduced fluid intake. The





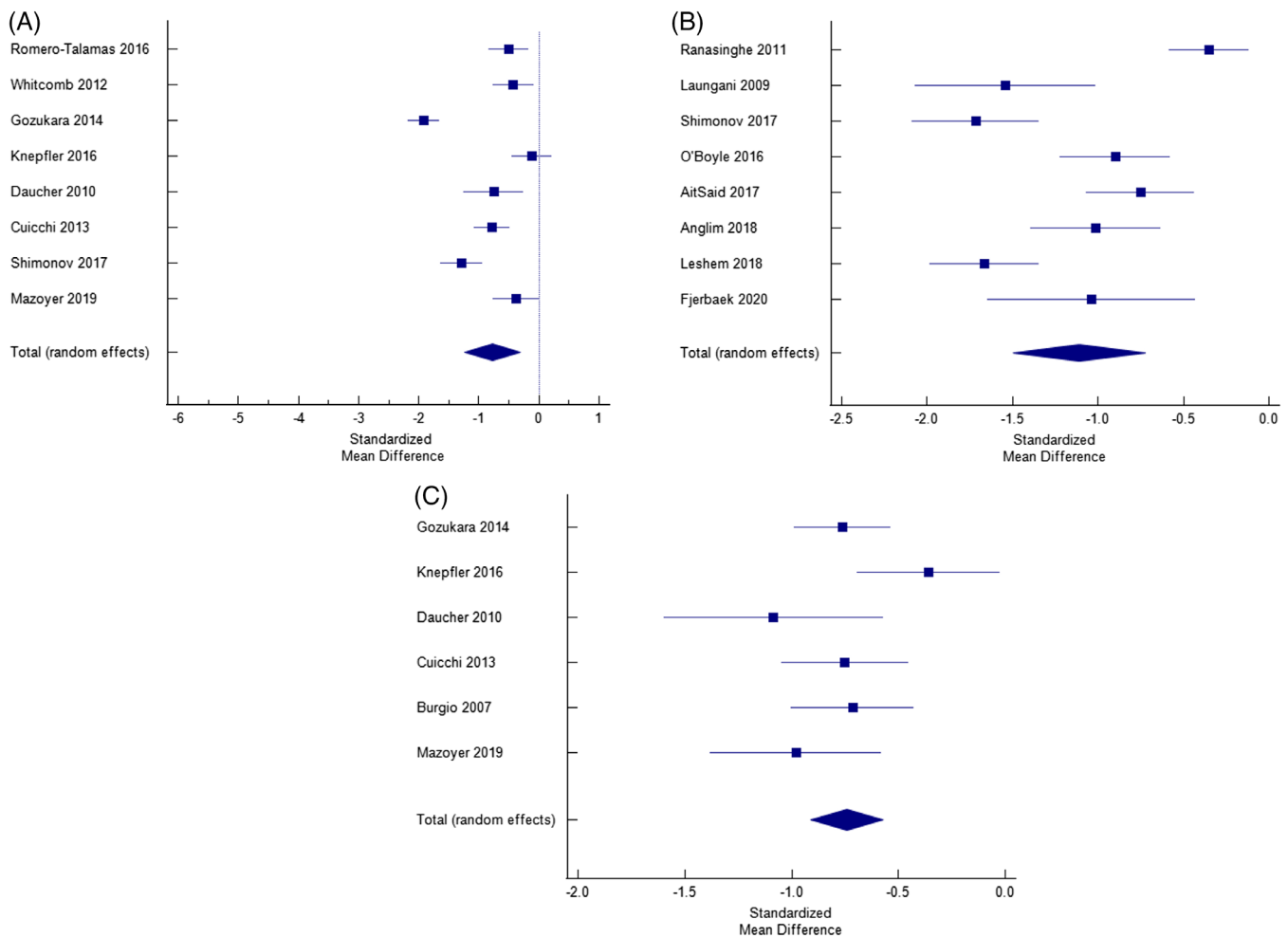
**FIGURE 6** Forest plot of OR values of urge urinary incontinence prevalence from all interventions (A), Surgical intervention studies (B) and behavioural (non-surgical) intervention studies (C)



**FIGURE 7** Forest plot of OR values of MUI prevalence from all interventions

changes in the amount of fluid intake or type of fluids being consumed may be contributing to the observed improvement in UII symptoms from the weight loss intervention studies, and not due to weight loss alone. Current understanding of the effects of these dietary factors on urgency symptoms would benefit from further research.

The impact on UI severity following weight loss was only reported in four of the included studies assessing bariatric surgery as an intervention. In each, the number of participants experiencing severe UI decreased significantly.<sup>35,40,42,45</sup> For example, in the study conducted by Kuruba et al, 49% of women complained of severe UI at baseline compared with only 13% at 12 months post-surgery. Furthermore, compared with surgical procedures that treat UI symptoms alone, bariatric surgery can provide further health benefits to obesity-related co-morbidities such as diabetes and hypertension, as well as improved mortality.<sup>63</sup> Despite the paucity in evidence that shows



**FIGURE 8** Forest plot of standardized mean difference in validated questionnaire scores; PFDI-20 (A), ICIQ-UI-SF(B) and UDI (C)

bariatric surgery-induced weight loss leads to significant improvements in UI severity, it is tenable that women with UI that are diagnosed with severe obesity (BMI  $\geq 35$  kg/m<sup>2</sup>), could be counselled on the plethora of benefits of bariatric surgery.

Adverse effects were not reported in any behavioural studies and only discussed in one study assessing bariatric surgery.<sup>30</sup> Adverse effects of bariatric surgery are well established and vary depending on the type of procedure carried out. Identifying all associated adverse effects is beyond the scope of this study but should nevertheless be taken into account if bariatric surgery is to be considered as a treatment option. In addition, the short-term cost of bariatric surgery, although beyond the scope of this review, is something to be considered. However, by preventing long-term complications of UI and other obesity-related comorbidities, it would likely prove cost effective in the long-term.<sup>64</sup>

The limitations of the present study include a disproportionately small number of controlled studies assessing surgical weight loss interventions on UI, compared to a large number of behavioural weight loss intervention studies most of which were randomized control trials. This highlights a paucity of randomized controlled trials evaluating the effects of surgical weight loss interventions on female obesity

related IU. The lack of comparison groups suggests the evidence provided by these manuscripts may be of low certainty.

Furthermore, there was a lack of consistency among the use of Patient Reported Outcome Questionnaires to evaluate patients' UI symptoms and QoL. This meant pooled analysis of scores from infrequently used questionnaires such as the IPSS, BFLUTS, SF-36, USP, and Sandvik severity scale could not be completed. Regarding heterogeneity, meta-analysis of study outcomes showed inconsistency was substantial for many of them ( $I^2 > 75\%$ ), despite using a random effects model. This heterogeneity was particularly evident across the outcomes of the surgical intervention studies and may be a result of different bariatric surgery techniques being used. Alternatively, this could be a result of inconsistent follow-up times across studies, some of which were likely too short for maximum weight loss to occur, hence limiting the significance of comparability.

The majority of studies used subjective measures for improvement in symptoms such as the common use of Patient Reported Outcome questionnaires<sup>9,22,24,26-32,34-52,54</sup> and voiding diaries,<sup>9,18,33,34,53,54</sup> which are arguably the most relevant for clinical care. However, compared with objective urodynamic measurements,<sup>9,26,29,33,51</sup> the results are

subject to patient response bias and their ability to accurately remember and complete these forms of assessment.<sup>65</sup>

## 5 | CONCLUSION

This is the first meta-analysis to study both bariatric surgery and behavioural weight loss interventions and their effects on UI, SUI, and UUI. Across all studies, weight loss was observed to be beneficial in improving UI. Specifically, bariatric surgery was associated with significantly reduced UI prevalence and sustained weight loss compared with behavioural interventions. The implication of these results from this study is that weight loss is an effective treatment for UI management in women with obesity. The authors of this paper recommend that more large-scale trials, with more robust study designs, are carried out to determine the relationship (linear or otherwise) between the degree of weight loss and impact on UI, and assess whether bariatric surgery should be offered to women with obesity-related UI, if other non-surgical UI management options have failed.

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## CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

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